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Numerical Modeling and Imaging of Near Surface Scattered Waves: An Approach of Turning Noise into Signal

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ABSTRACT

In land seismic data, scattering from surface and near-surface heterogeneities adds complexity to the recorded signal and deteriorates weak primary reflections. Although the scattered waves can be a challenging source of noise in many seismic data applications, they provide an optimal illumination of the near surface and, therefore, can be treated as signals that reveal more information about the source of scattering or the heterogeneities. The knowledge of location and strength of the scatterers helps seismic imaging, survey planning, and avoid drilling geo- hazards.

To understand the effects of near-surface complexities on seismic reflections, seismic-wave scattering from arbitrary- shaped, shallow, subsurface heterogeneities is simulated through the use of a perturbation method for elastic waves and finite-difference forward modeling. The scattered field is shown to be equivalent to the radiation field of an equivalent elastic source excited at the scatterer locations. Moreover, the scattered waves consist mainly of body waves scattered to surface waves and are, generally, as large as, or larger than, the reflections.

Based on the analysis of the simulated results, an elastic reverse time migration (RTM) approach is introduced for imaging near-surface heterogeneities, such as karst features, using scattered waves (e.g., body to P, S, and surface waves). The approach back-projects the scattered waves until they are in phase with the incident waves at the scatterer locations. An elastic staggered-grid finite-difference scheme is used to model seismic wave propagation for RTM. The scattered body-to-surface waves provide an optimal illumination aperture of the near surface, as they travel along the free surface with wide wavenumber coverage. The robustness of the elastic RTM approach is demonstrated on simulated seismic data.